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Rapid land use change threatens provisioning ecosystem services in miombo woodlands

Eleanor K.K. Jew , Oliver J. Burdekin, Andrew J. Dougill and Susannah M. Sallu

Abstract

Rural communities in sub-Saharan Africa rely upon provisioning ecosystem services (ES) to support their livelihoods, yet in areas where rapid land use change is occurring the relationship between environmental change, provisioning ES availability and livelihoods is not fully understood. This relationship is explored here within a typical rural miombo woodland landscape in south-west Tanzania, which is undergoing rapid land use change due to expanding tobacco cultivation. The types of provisioning ES used, who uses them, changes in their availability, and the possible future impacts of these changes were explored using a mixed-method approach. Our findings identify 19 provisioning ES used by households regardless of economic status. Firewood, building materials, and fresh water are used by almost all households, and these are perceived to be declining in availability. Households identified this as a negative environmental impact of land use change and that provisioning ES loss would be 'bad' for their households. Given the multi-purpose nature of miombo woodlands, an adaptive co-management approach, which can achieve multiple objectives through encouraging participation, learning, and empowerment of local communities, could be an appropriate strategy to achieve sustainable land use management and maintain the provision of ES within miombo woodland landscapes of sub-Saharan Africa.

Keywords: Livelihoods; rural poor; Tanzania; deforestation; non-timber forest products.

1. Introduction

Ecosystem services (ES) are the direct and indirect contributions of ecosystems to human well-being (de Groot *et al.*, 2010). The Millennium Ecosystem Assessment framework divides ES into four categories: provisioning services - the products obtained from the ecosystem, such as food, fibre, fuel, and fresh water; regulating services—the benefits obtained from the regulation of ecosystem processes such as water purification and pollination; cultural services—the non-material benefits obtained from cultural heritage, recreation and tourism; and supporting services—necessary for the production of other services, such as soil formation, photosynthesis and nutrient cycling (MEA, 2005). Globally, human activities have resulted in a 60% decrease in the services provided by ecosystems (MEA, 2005). While all types of ES are important to human well-

being, basic provisioning services are recognised as essential for meeting human needs (Daniel *et al.*, 2012), with the livelihoods of the poor considered to be the most dependent (Carpenter *et al.*, 2006; Suich *et al.*, 2015). Land use change has a significant impact on the availability of ES (Metzger *et al.*, 2006). However, the linkages between land use cover, the availability of ES, and people's use of these services have been understudied (Rasmussen *et al.*, 2016). This is particularly the case in sub-Saharan Africa, where the sustainable management of ES is vital for the livelihoods of the rural poor (Zhang *et al.*, 2016), and especially for dry sub-humid miombo woodland landscapes (Ryan *et al.*, 2016).

This study seeks to address this research need by exploring the provisioning ES use by the local communities within a remote miombo woodland landscape experiencing rapid land use change in south-west Tanzania. Interdisciplinary, multi-method approaches to assess the use, availability, and distribution of provisioning ES are frequently called for (Guerry *et al.*, 2015; Rasmussen *et al.*, 2016), yet are infrequently adopted. This study combines ecological and social methods to generate quantitative and qualitative data. Household surveys are used in combination with focus groups, interviews, observations (e.g., Kalaba *et al.*,

Eleanor K.K. Jew, Andrew J. Dougill and Susannah M. Sallu are at the Sustainability Research Institute, School of Earth and Environment, University of Leeds, Leeds, UK. E-mail: eleanor.jew@york.ac.uk; a.j.dougill@leeds.ac.uk and s.sallu@leeds.ac.uk

Oliver J. Burdekin is at burdGIS, Wakefield, UK. E-mail: oliverburdekin@burdgis.com

2013, von Maltitz *et al.*, 2016, Dave *et al.*, 2017), and ecological assessments to provide a holistic understanding of the role of ES within the socio-ecological system, and thus guide a more nuanced management strategy.

The deciduous miombo woodlands of sub-Saharan Africa extend for approximately 2.4 million km² (Frost *et al.*, 2003) and support the livelihoods of at least 100 million people (Syampungani *et al.*, 2009, Dewees *et al.*, 2011) through a range of goods and services, leading them to be described as “a pharmacy, a supermarket, a building supply store, and a grazing resource” (Dewees *et al.*, 2010: 61). They are also of global importance as a carbon store (Ribeiro *et al.*, 2015). Rapid land use change in these woodlands is occurring and is anticipated to continue (Ryan *et al.*, 2016), leading to degradation with potentially devastating consequences for the livelihoods that they support. Tobacco cultivation is a leading cause of land use change and is common within miombo woodlands due to the suitability of the sandy soils and plentiful wood, which are needed to cure the leaves for storage (Geist, 1999). However, tobacco is nutrient hungry (Baris *et al.*, 2000) and miombo soils are poor (Frost *et al.*, 2003), therefore woodland is constantly cleared to continue to grow or expand cultivation (Sauer and Abdallah, 2007). This leads to deforestation, degradation (Lecours *et al.*, 2012), and expansion of the agricultural frontier. Furthermore, economic incentives from tobacco cultivation drives immigration and increases the demand for forest products and ES, yet access to miombo woodland is rarely regulated and the capacity to restrict overuse is weak (Luoga *et al.*, 2005). Several studies on ES provision and use within miombo woodlands have found that the use of provisioning ES is extensive and that they are disproportionately used by the rural poor (Syampungani *et al.*, 2009; Dewees *et al.*, 2011; Njana *et al.*, 2013). However, it is not known how environmental changes resulting from land use will affect this relationship in the future (Ryan *et al.*, 2016) particularly in remote areas, and what impact this loss will have on local communities. Consequently, this paper examines: (1) the types of provisioning ES used and by which households to determine who will be vulnerable to future changes; (2) the perceived changes in the availability of these services in areas where land use change is occurring; and (3) what this may mean for the future management of miombo woodlands.

2. Materials and methods

A remote rural landscape within the Kipembawe Division (8,766 km²) in the Chunya District, Mbeya Region of south-west Tanzania (7°54'58.44" S, 33°19'22.84" E, Figure 1) was selected for study. This area is dominated by miombo woodland, characterised by the presence of three tree genera (*Brachystegia*, *Julbernardia* and *Isoberlinia*) in a high rainfall regime (mean annual precipitation

933 ± 36 mm (min 602 mm, max 1466 mm)), and is representative of other areas of miombo woodland across the region. Agriculture is the main livelihood for the estimated population of 66,752, distributed across 16 villages with an average annual population growth rate of 3.5% (National Bureau of Statistics, 2013). Access to woodland and the extraction of poles and timber for personal use is unregulated, apart from three forest reserves under the jurisdiction of the District Forestry Department and five Participatory Forest Management (PFM) reserves, which are overseen by village-level PFM committees. Hunting and logging permits are issued at district level. Land tenure is governed through village councils in line with typical forest management conditions experienced across the miombo region (Luoga *et al.*, 2005; Kalaba *et al.*, 2013).

Rainfall occurs from October to May and the average temperature is 22.2 ± 2.7°C. Fieldwork for this study took place from March to September 2013.

2.1. Data collection

A mixed methods approach combining ecological and social surveys was used. Nine ecological survey sites, representing low to high levels of human utilisation of woodland were selected (described in Jew *et al.*, 2016). Sites were a minimum of 10 km apart. Six woodland-adjacent villages were chosen for study in the social survey, one of which was used as a pilot study (‘Pilot’ village, Figure 1). There are two larger villages in Kipembawe, which have markets and a range of small shops where people can get a range of supplies not available in smaller villages. These are marked as ‘supply’ villages on Figure 1.

At each ecological survey site, five transects (250 m apart, running north-south, 1.5 km long) were established to record land use type and utilisation of the woodland. Transects sampled 75,000 m² at each site, were 10 m wide and divided into 20 m sections (Doggart, 2006). Within each section, all live, dead, and cut poles and timbers were recorded. Evidence of all other types of human utilisation, extraction of timber, and non-timber forest products was noted. The Global Forest Change dataset (Hansen *et al.*, 2013) was used to determine forest loss in this area between 2000 and 2017, as identified through the time-series analysis of Landsat data.

Following Meshack *et al.* (2006), we randomly selected 10% of households to participate in the research and invited the household head (defined as the primary decision maker) to participate. For the purposes of this research, a household is defined as people who eat from the same pot and sleep under the same roof (Knueppel *et al.*, 2010). In total, 196 surveys were conducted, each lasting approximately 40 minutes and included closed and open questions.

Focus group discussions (Morgan, 1997) were conducted in each village consisting of 2–8 male and female participants from specified groups of people such as

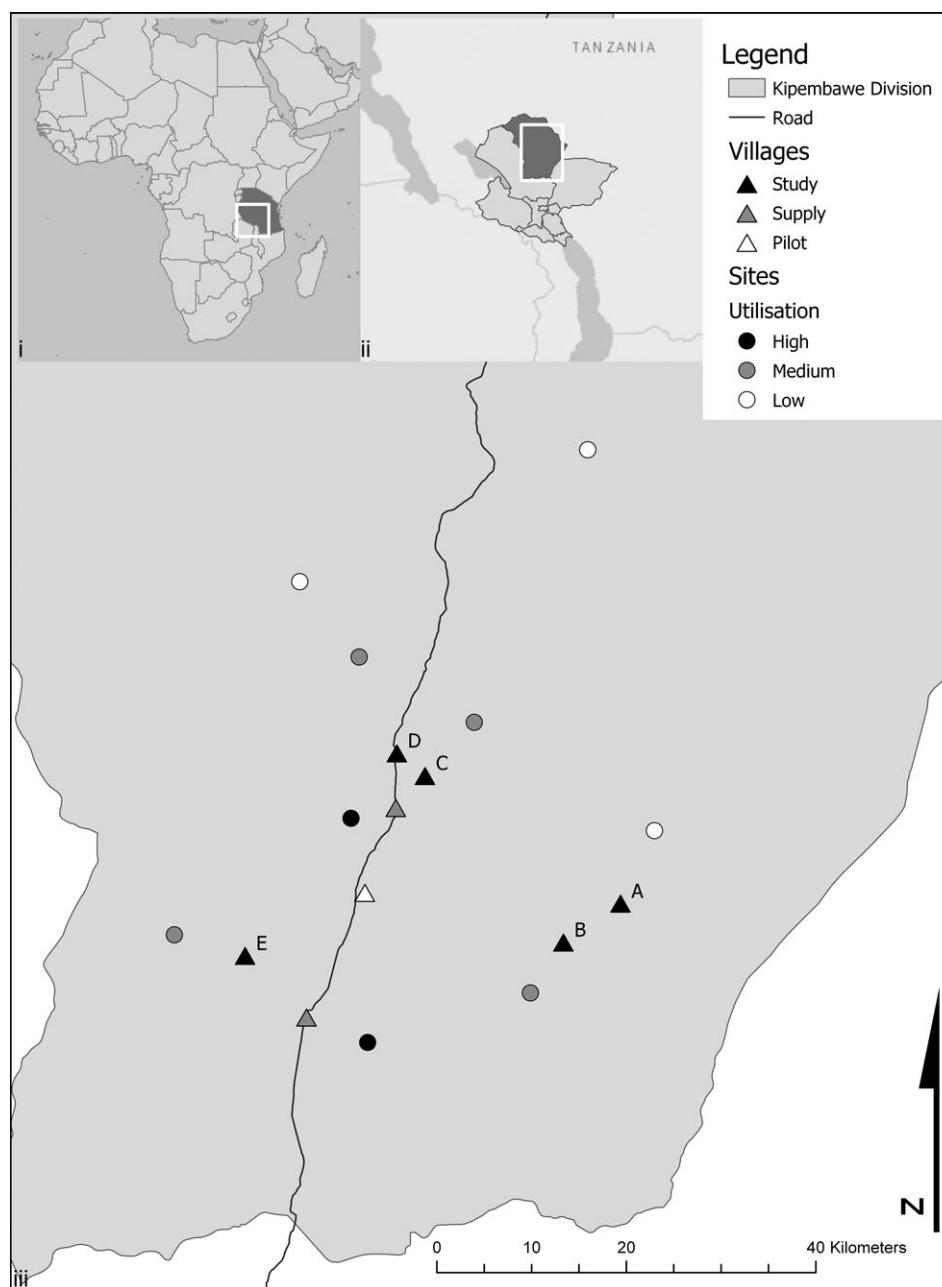


Figure 1. Study site location in the Kipembawe Division (iii), within Mbeya (ii), Tanzania (i). Villages and ecological survey sites are illustrated (created from GADM, 2015; Sandvik, 2009; ESRI, 2018b).

pastoralists (4 groups), agriculturalists (5), villagers (5), village elders (5) and relevant committees within each village (PFM (2), social welfare committee (5), land use planning (2)). Focus group participants were volunteers and their participation was facilitated by the village or sub-village chairperson, who worked with the research team to identify suitable participants for each type of focus group. The focus groups were conducted to gather detailed qualitative information on topics relevant to the group, exploring key themes and questions arising from household surveys. A series of questions was considered among the group with facilitation (Ritchie

et al., 2013). Responses were grouped into themes for analysis.

Key informants at village, ward, division, district and regional levels were invited to participate in semi-structured interviews. Participants were determined using snowball sampling, with 41 representatives from government, private companies, and non-governmental organisations interviewed. Key informants were associated with natural resource management and village governance, subjects that had arisen through focus groups and household surveys. Key informants have been coded throughout to ensure anonymity.

The wealth status of each household was ascertained unobtrusively based on indicators from elsewhere in Tanzania (Van Campenhout, 2007). Indicators used included the materials of the house and roof, quality of clothing, and visible assets (e.g., bicycle, solar panels, motorbike). Households were classified based on their perceived wealth status compared to the rest of the community into five groups (much better off, better off, average, worse off, and much worse off).

2.2. Data analysis

A range of methods was deployed to determine the provisioning ES used within each village. During a pilot study, open questions were asked to identify all potential provisioning ES to produce an exhaustive list of locally relevant provisioning ES. During the survey, each household was asked whether they used each service indicated on the list, how often they used them, from where they were obtained, and whether they were for home use, sale, or both. Within each village, a focus group took place dedicated to determining the use of provisioning ES and the degree to which people relied on the woodland for income. Woodland visits were conducted with traditional healers to understand local uses of plants and trees. Utilisation of poles and timber was determined by calculating the proportion of cut poles and timbers within the available poles and timbers (dead and alive). All other signs of utilisation, such as pitsaw sites, beehives, rope extraction, and bark removal, were counted and summed across sites.

Daily rainfall data recorded at the Lupatinginga Weather Station from 1977 to 2014, and levels of the River Lupa, recorded twice daily from 1975 to 2014 (Lake Rukwa Water Basin River Board, 2014), were analysed. To determine whether annual rainfall has changed over time, the Mann-Kendall trend test was performed in R (McLeod, 2011). To determine river levels, the daily average height of the river was calculated, and these data were used to calculate average monthly levels per year for the full data set. Data throughout the 1990s were collected irregularly, so to determine whether there has been a change in water levels over time, the average monthly levels were calculated using 8 years of complete data, where available, between the periods 1975–1993 and 2005–2014. Water availability was also discussed within the village focus groups and with key informant interviews.

To identify trends in particular characteristics of ES users, a generalised linear model (function *glm*) with two way model selection (function *stepAIC*, MASS package; Venables and Ripley, 2002) was performed on total ES used and five categories: wealth, household size, time resident in area, village, and age of respondent. To further test the relationship between wealth and individual ES (rope, building poles, grasses for construction,

mushrooms, fruits, vegetables, wood for tools, and total ES used), a generalised linear mixed effects model was used (function *glmer* in package *lme4* (Bates *et al.*, 2014)) with ‘village’ as the random effect. First, the inter-relationships between all variables were tested for correlation using the Pearson’s correlation test. Variables that were not highly correlated were used ($r < 0.7$) (Loos *et al.*, 2014). The Mann–Whitney U test was used to explore linkages between the average number of ES used per household in each village, the distance of the village from the main supply village, and the percentage of harvested poles and timber (utilisation) at the nearest ecological survey site. Statistical analyses were conducted using the statistical package R, version 3.1.0 (2014-04-10) (R Core Team, 2014).

To identify perceived changes in the availability of ES over time, household survey respondents were asked how often they used each resource to capture seasonality and if they had noticed changes in availability during the time that they had been resident in the village to identify inter-annual rather than intra-annual change. Time living in village were categorised into 0–5 years, 6–10 years, 11–20 years, 21–30 years, 31–39 years, and 40+ years. Perceived changes in availability of ES over time were pooled per village and across all villages. Where no clear consensus of trend was revealed, the data were tested for significant differences between responses for all pooled data, per village, and timeframe using Fisher’s exact test. Similar questions were posed during focus groups and key informant interviews.

To identify the impact of changes in provisioning ES availability on households, survey respondents were asked how they would be affected if the provisioning ES they used were not available in the future. They were also asked what they thought the village and environment would look like in 10 years’ time. Responses were coded and pooled across villages. This theme was also explored within focus groups and key informant interviews.

Forest loss was calculated through analysis of the Global Forest Change dataset (Hansen *et al.*, 2013). To identify forest loss since 2000, these data were grouped into three time bins (2000–2007, 2008–2013, and 2014–17) based on data availability (since 2000), the results of key informant interviews, and focus groups (Section 3.1). To determine forest loss around villages, which are key areas for the extraction of ES, a 5 km buffer was created around each survey village. This was based on the average distance walked by households to collect firewood as determined through the household survey. Within each buffer zone, the Global Forest Change dataset (Hansen *et al.*, 2013) was used to determine forest cover in the year 2000, classified as 30 × 30 m cells with a percentage forest cover value >10% (FAO, 2002). Percentage forest loss was calculated per year for each village buffer. Analysis was performed using ArcMap 10.6 (ESRI, 2018a).

3. Results

3.1. Land use change

According to the focus groups with village elders, Kipembawe was sparsely populated by hunter gathers prior to the 1960s (Jew, 2016). Tobacco cultivation was introduced to the area as part of successive government village settlement schemes in the late 1960s and 1970s. Both the population and tobacco production grew slowly until the tobacco industry was privatised in the 1990s (Mitchell and Baregu, 2012). Key informant interviews suggested that

rapid land use change had been taking place in the area, which was described by a district official: “Deforestation rates are very high, it is a big problem” and by division officials: “Before there was a big forest, now it is small”; “There have been big changes [in the forest] in the last five years”. This coincides with a second private tobacco company establishing production in the area in 2008, and forest loss is evident through the analysis of the Global Forest Change dataset (Figure 2). Jew *et al.* (2017) identified tobacco cultivation as the main driver of land use change due to land clearance to plant the crop and for fuel to dry tobacco leaves, resulting in an annual deforestation rate of

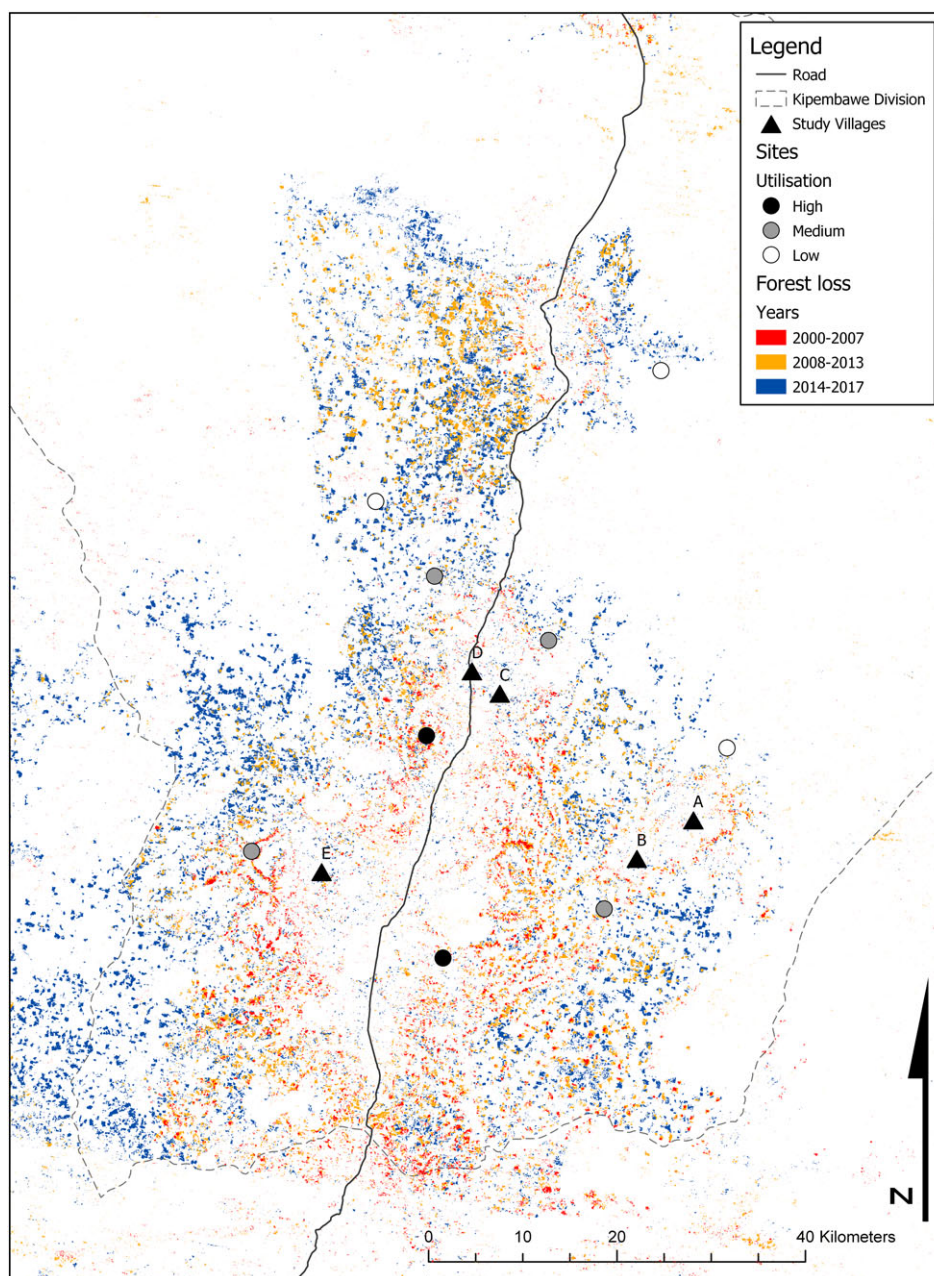


Figure 2. Forest loss in Kipembawe 2000–2017. Source: Hansen/UMD/Google/USGS/NASA. https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.5.html.

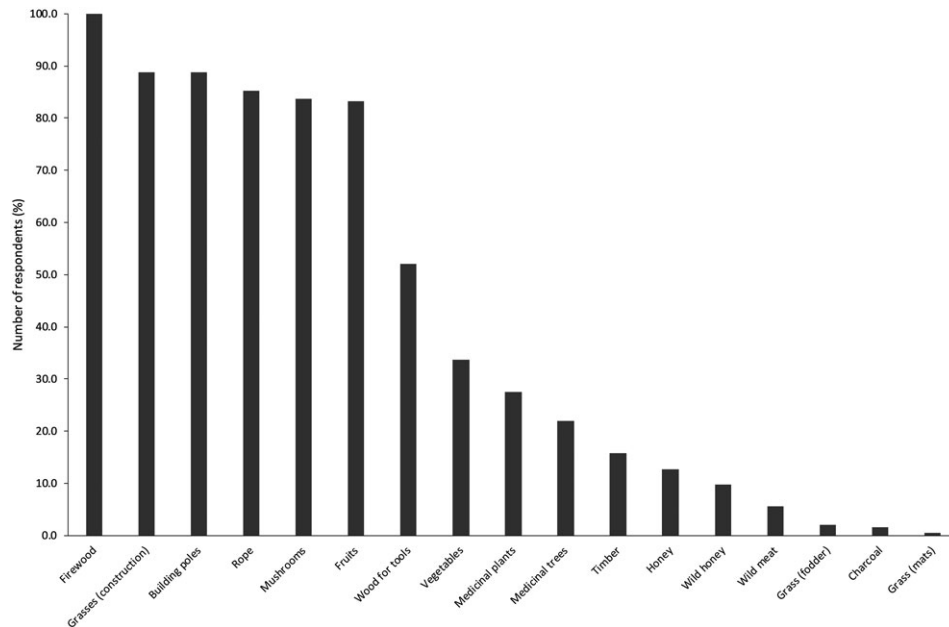


Figure 3. Percentage of households using each provisioning service (household survey, $n = 196$). Honey is defined as being harvested from designated beehives; ‘wild’ honey is that from natural hives.

Table 1. Areas of provisioning ES collection by households. Households collecting from each area - multiple answers could be given (household survey, $n = 196$)

Ecosystem service	Area ES collected					
	Personal land*	Open access woodland	No particular area	Seasonal Floodplain	Bought from other villagers	Other [†]
Firewood	129 (65.8%)	6 (3.1%)	63 (32.1%)	0	1 (0.5%)	13 (6.6%)
Building poles	117 (59.7%)	42 (21.4%)	19 (9.7%)	0	0	7 (3.6%)
Grasses for construction	72 (36.7%)	36 (18.4%)	35 (17.9%)	28 (14.3%)	7 (3.6%)	3 (1.5%)
Mushrooms	122 (62.2%)	51 (26%)	13 (6.6%)	0	0	5 (2.6%)
Fruit	94 (48%)	46 (23.5%)	38 (19.4%)	0	0	7 (3.6%)
Vegetables	19 (9.7%)	45 (23%)	1 (0.5%)	0	0	19 (9.7%)
Medicinal trees and plants	38 (19.4%)	24 (12.2%)	28 (14.3%)	0	0	1 (0.5%)
Rope	131 (66.8%)	29 (14.8%)	14 (7.1%)	0	0	8 (4.1%)
Wood for tools	55 (28.1%)	30 (15.3%)	21 (10.7%)	0	0	3 (1.5%)

Notes: *Personal land is that which is held in tenure/allocated to the household by the village or claimed. On average, each household held 3.8 ha of agricultural land and 12.1 ha of natural woodland.

[†]‘Neighbours’ land, village woodland, regenerating woodland, termite mounds.

4,134 ± 390 ha, which if unchecked, will result in total loss of woodland in Kipembawe in less than 200 years. Additional direct drivers were extraction of wood for construction and household use, and degradation due to pastoralism; while indirect drivers were demographic (immigration) and economic (rising tobacco prices) (Jew *et al.*, 2017).

3.2. Provisioning ES use and users

During the household surveys, 17 provisioning ES were identified as used by households (Figure 3). Similar lists

were produced by focus groups within each village, with the addition of ‘fish’ and fresh water; therefore 19 provisioning ES were identified in total.

Provisioning ES are collected from a range of areas (Table 1). All respondents depend on firewood from the miombo woodlands for their energy needs. The importance of the woodlands for energy was also highlighted by Regional Officer 2: “People rely on the forest, especially for energy”. All but two households collected it themselves. Ten respondents also used charcoal for cooking with four charcoal pits observed during the ecological surveys.

Grasses were used for construction by 174 (88.8%) of respondents, of whom the majority collected them personally apart from seven (4%) households who bought them and two households (1.1%) who employed people to cut grasses for them. Timber was used by 31 (15.8%) households, of whom 19 (61.3%) bought it locally and one bought it ‘from town’. One household bought both poles and timber from Mbeya. One household used mountain bamboo for building poles. All other poles, timber, and grasses were harvested by the household. Cut poles and timbers were recorded on transects, however it is difficult to differentiate between that harvested for construction use and that harvested for use in tobacco burners. Nine pitsaw sites, eight incidents of logging, and six incidents of discarded timber were recorded during ecological surveys. District Officer 3 said that “there are many illegal loggers”.

Medicinal plants and trees were used by 58 (29.6%) households. Woodland walks with forest users and traditional healers provided an insight into the uses of miombo products, as listed in Supplementary Material Table A. Mushrooms, fruit, and vegetables are used by most households; these are seasonal produce, which is harvested annually. Wild meat was used by 11 (5.6%) households, of whom eight (72.7%) bought it from local hunters. Hunting is illegal without a licence, so this may have affected response rates. However, both Village A Officer 3 and Village D Officer 3 said that there was “very little” poaching in the area. Village A Officer 3 went on to say that occasionally eland, buffalo, and hartebeest are poached for food, and that occasionally this is sold locally, but it happens rarely. This may vary from village to village—in Village C, the research team was offered eland meat, and during ecological surveys at the adjacent site there were

encounters with poachers, gun shots heard, and baited poison for baboons found.

The collection of provisioning ES to sell was limited: one household collected fruits, two households collected grasses for construction, one household collected grasses to make mats to sell, one household collected building timber, two households collected honey from beehives, and one person collected wild honey for sale. There were 187 signs of activities relating to honey production on the ecological survey transects.

To determine who uses each type of ES, the relationships between the household and village characteristics, and the use of ES were examined. Two-way stepwise selection for a generalised linear model based on AIC demonstrated that there were no significant associations between the total number of ES used and wealth, age of respondent, length of time in area, and household size. However, there was a significant difference between the number of different services used by households between the villages, with households within Village E using significantly fewer provisioning ES than households within the other villages (GLM, $df = 191$, $\chi^2 = 102.62$, $P = 0.00377$).

Mann–Whitney U tests did not demonstrate a significant relationship between the number of ES used and the distance to the nearest supply village ($P = 0.6905$) nor with utilisation in adjacent ecological survey sites ($P = 0.1508$). However, these results suggest a correlation indicating that more ES are used when the distance to the nearest supply village is greater, and that fewer ES were used in areas that were heavily utilised. Additionally, there were no significant relationships between the wealth status of households and the type of ES used (Table 2 and Supplementary Material Figure A).

Table 2. Relationships between use of ES and wealth of household, calculated using a generalised mixed effect model with ‘village’ as the random effect

Ecosystem service	Predictor variable	Estimate	SE	Z	Pr > z)
Rope	Intercept	−0.09148	0.21461	−0.426	0.670
	Wealth	−0.02055	0.06023	−0.341	0.733
Building poles	Intercept	−0.105619	0.212321	−0.498	0.619
	Wealth	−0.004007	0.059192	0.068	0.946
Grasses for construction	Intercept	−0.08211	0.21144	0.389	0.697
	Wealth	−0.01101	0.05911	−0.186	0.852
Mushrooms	Intercept	−0.29799	0.22398	−1.330	0.183
	Wealth	0.03536	0.06148	0.575	0.565
Fruit	Intercept	−0.23227	0.22178	−1.047	0.295
	Wealth	0.01422	0.06138	0.232	0.817
Vegetables	Intercept	−1.101794	0.346392	−3.181	0.00147**
	Wealth	0.003968	0.096260	0.041	0.96712
Wood for tools	Intercept	−0.64384	0.28251	−2.279	0.0227*
	Wealth	−0.00500	0.07831	−0.064	0.9491
Total ES used	Intercept	1.932258	0.080653	23.959	<2e-16***
	Wealth	0.008824	0.021701	0.407	0.684

Note: Significance levels indicated by: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

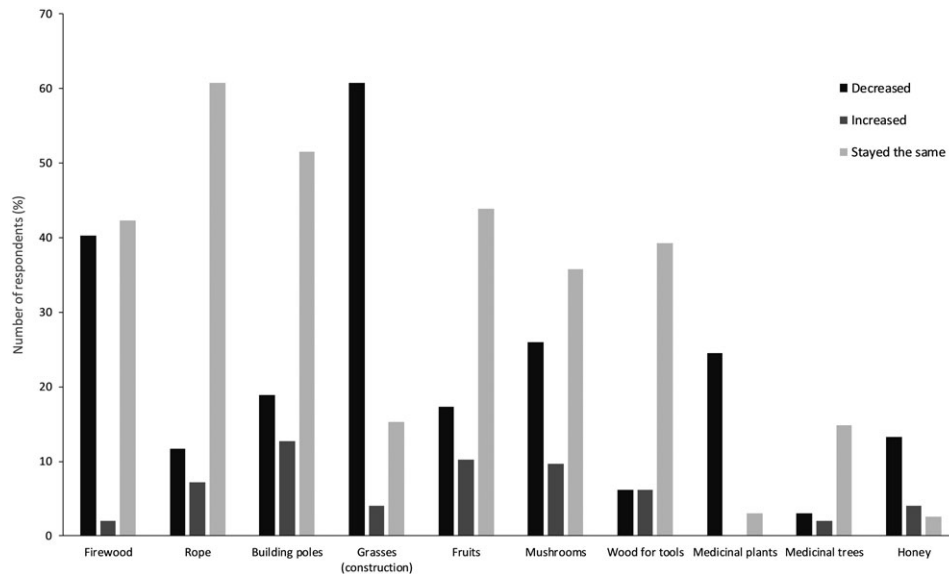


Figure 4. Perceived trends in availability of ES during the time the respondent was resident in the village. *Note:* household survey, $n = 196$.

3.3. Changes in availability of provisioning ES

Perceptions of the trends in availability of each service varied considerably. Grasses that could be used for construction and medicinal plants were widely thought to be decreasing over time. The availability of rope and building poles was thought to be stable. Very few respondents thought that any services were increasing in availability (Figure 4). For some services (mushrooms, firewood, and fresh water), there was considerable ambiguity in the perceptions and these were analysed further.

Respondents in Village C and Village D thought that firewood availability had declined (Fisher's exact test (FET): Village C: $P = 0.02$; Village D: $P < 0.004$). Respondents in Village B (FET, $P = 0.01$) and Village E (FET, $P < 0.004$) felt that firewood availability had stayed the same. In Village A, there was no significant difference between those who thought that firewood had decreased and those who thought it had stayed the same ($P = 0.19$). Forest loss is occurring around the villages (Figure 5) and the highest rates are seen around villages B and E, where firewood availability was thought to be the same, and lower rates in villages C and D,

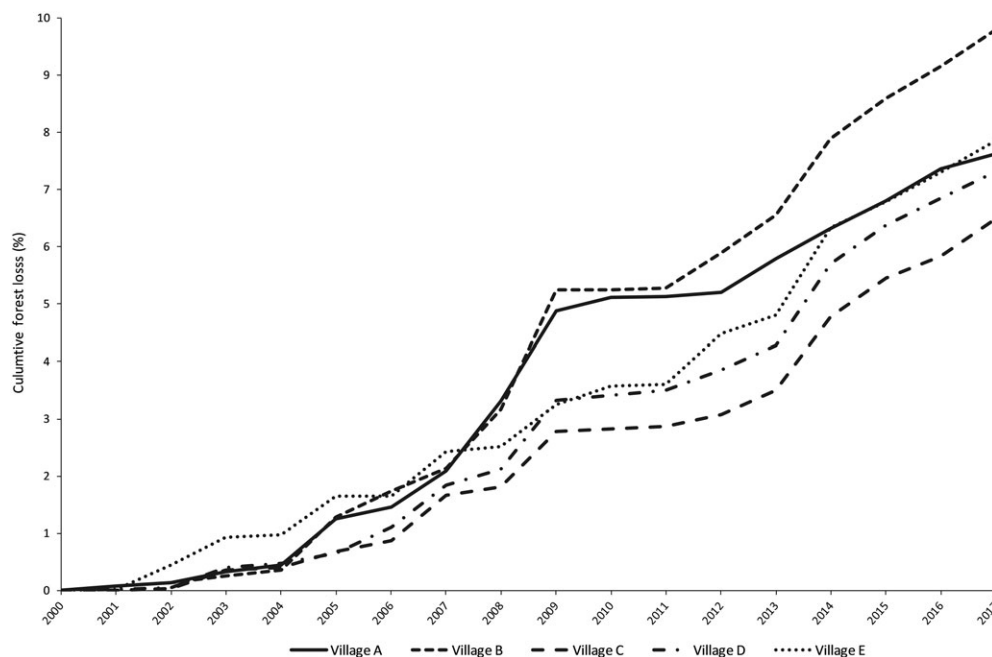


Figure 5. Cumulative forest loss (%) for 5km buffer zones around each village. *Source:* Hansen/UMD/Google/USGS/NASA.

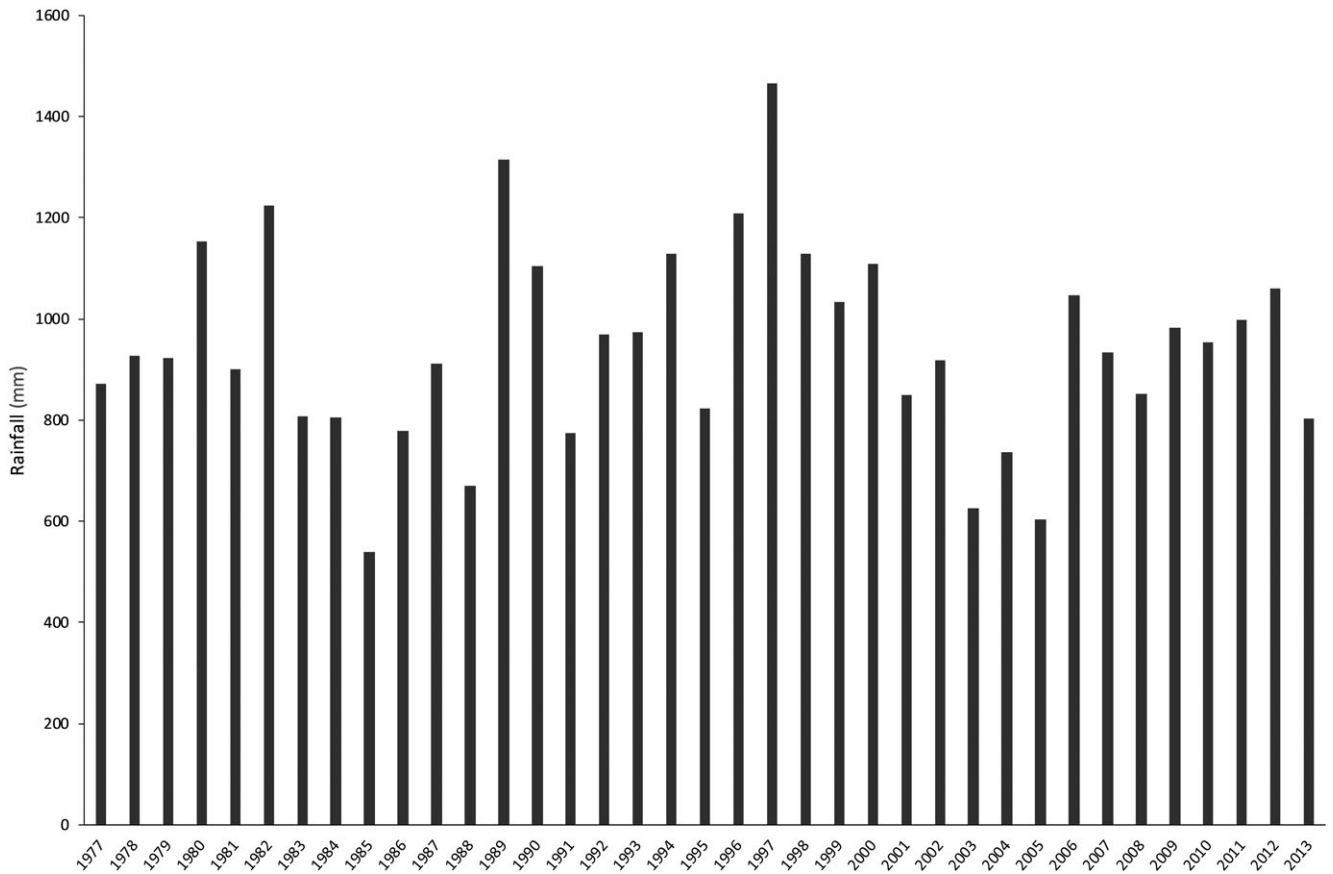


Figure 6. Trends in annual rainfall 1976–2013, Lupatingatinga. *Source:* Lake Rukwa Water Basin River Board (2014).

where firewood availability was thought to be decreasing. This could be due to the location of deforestation—average time to firewood destination in villages B and E were

32 and 35 minutes respectively, whereas in villages C and D average times were 50 and 43 minutes respectively. This suggests that forest loss may be taking place closer to the

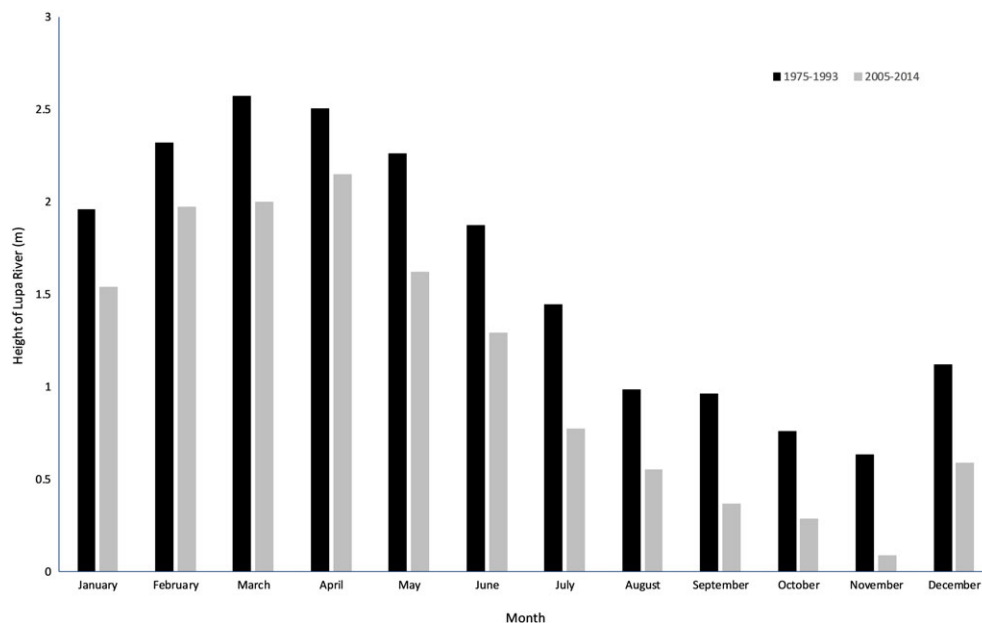


Figure 7. Height of the River Lupa per month between 1975–1993 and 2005–2014. *Source:* Lake Rukwa Water Basin River Board (2014).

Table 3. Effect on household if provisioning ES are no longer available from woodland (household survey, n = 196). Don't know (n = 15), no answer (n = 7)

It will be bad for my household because... (n = 152)	Number of responses	Percent (%)	It will not affect my household because... (n = 22)	Number of responses	Percent (%)
We depend on the forest for everything	97	63.8	I will move away	2	9.1
It will have a negative financial impact	16	10.5	We will find alternatives	6	27.3
It will affect tobacco cultivation	5	3.3	We plant our own trees	3	13.6
No alternative way to cook food	29	19.1	Don't use them enough to have an impact	7	31.8
[But] the forest will always be there	9	5.9	Other	4	18.2
It will affect the climate/no rainfall	4	2.6			
I will move away	4	2.6			
It will have an effect on inheritance/spiritual values	2	1.3			
It will affect development activities	1	0.7			
Don't know	1	0.7			

villages in Village C and D, meaning that it is necessary to walk further to collect firewood. There were no significant trends detected in respondents' opinions according to the length of time that they had been in the area. Perceptions in the availability of mushrooms did not show any clear spatial or temporal trends.

A perceived reduction in the availability of water was apparent. This was demonstrated by the Village A focus group: "Water is the most important part of the environment. It is available, but it is not good for drinking, because we use the same water as other people wash in. Getting clean water for drinking is a problem". Awareness of water issues extends to regional levels: "The water table is becoming lower as everyone is digging boreholes, and an increased demand for water is increasing conflict over water, as there are increasing numbers of cattle that need water. The demand for water is increasing, but its availability is decreasing" (Regional Officer 3). The availability of water has led to water restrictions in one village: "Since 2012 we have restricted people to 3-4 buckets of water a day per household" (Village E Officer 1, 2013). People believed that the forest cover has an impact on the amount of rainfall that they receive: "We depend on the forest for rainfall" (Village B and E Villager focus groups,

2013): "The main source of the reduction in rainfall is tobacco cultivation, because of the cutting of trees" (Village B Officer 1, 2013). All five village elder focus groups thought that the amount of rainfall had decreased over time and that river levels had decreased.

The volume of annual rainfall recorded in Lupatinga-tinga varies considerably annually (Figure 6), however, there is no evidence of long term declines (Mann-Kendall trend test $\tau = 0.00901$, two sided P value = 0.94786). Water levels at the River Lupa have decreased by 14–90% per month between 1975–1993 and 2005–2014 (Figure 7).

3.4. Perceptions of the future

According to 152 (77.6%) of those sampled, it would be "bad" for households if the woodland was no longer able to provide the provisioning ES used, whereas 22 (11.2%) respondents thought that it would not affect them (Table 3). Many of the people who thought it would be bad for the household had similar opinions: "The forest will always be there, there is no way of surviving without it" (household survey, Village C); "We depend on the forest for everything" (household survey, Village E). One person who thought that it would not affect the household said, "I

Table 4. How will the environment look in 10 years' time? (Household survey, n = 196). Don't know (n = 25), no answer (n = 6)

Farmland	Number of responses	Percent (%)	Woodland	Number of responses	Percent (%)
Agricultural expansion	22	13.3	No trees	51	30.5
Land shortage (for agriculture)	35	21.2	Reduced forest	1	0.6
Conservation awareness will increase	1	0.6	Regenerated forest only	1	0.6
Desert	35	21.2	No change	35	21.2
Drought/no water	21	12.7	Environmental destruction	5	3.0
People will move away	1	0.6	Moved by TANAPA – it will be a Reserve	2	1.2
Infertile soils	24	14.5	More forest	2	1.2
No agriculture	6	3.6	No rain	5	3.0
Tractors	2	1.2			

Table 5. What will the village be like in 10 years' time? Household survey (n = 196). Don't know (n = 30), no answer (n = 2)

What will the village be like in 10 years' time?	Number of responses	Percent (%)	What will the village be like in 10 years' time?	Number of responses	Percent (%)
<i>Positive</i>			<i>Other</i>		
Better communication network	4	2.4	No change	4	2.4
Better transport infrastructure	19	11.6	Change in population because of tobacco price	3	1.8
Better water supply	9	5.5	Population increase	38	23.2
Electricity	10	6.1	Low population - others will go back to their hometowns or move away	3	1.8
Improved education	7	4.3	More livestock	2	1.2
Improved infrastructure – hospitals, market areas, small businesses	10	6.1	Village will expand	15	9.1
More skilled people	1	0.6	Village will shift to a town and the rest of the area will be farm and forest	1	0.6
More maize processors	2	1.2			
Modern houses – tin roofs rather than grass	52	31.7			
More developed	64	39.0			
More livelihood activities	2	1.2			
<i>Negative</i>					
Less development - irresponsible leaders	7	4.3			
It will be very hard here because of the damage to the environment - clearing trees, burning, water source damage. No farmland, no forest.	3	1.8			
No electricity	3	1.8			
No water - because now it is scarce	2	1.2			
A Reserve here - it will be taken by TANAPA	2	1.2			

don't depend on it much because I have [products on] my farmland" (household survey, Village B); others thought that they would have to find alternatives. Village A focus group said that the forest did not just provide these services, but it also acted as a windbreak and provided water, so without it the place would be "like a desert". They also said that the single most important thing about the forest is the trees, because they need them for drying the tobacco.

When asked to consider how the environment may look in 10 years' time, the majority of the responses were negative (Table 4): for example, 31% of household survey respondents thought that there would be no trees and 40% thought that there would be issues with water (desert; drought/no water; no rain). The reasons given for these changes included "cutting trees", "tobacco cultivation", "livestock", and "increased population".

When asked to consider how the village may look in 10 years' time, the majority of the responses were positive (Table 5). The most frequently proposed positive changes included greater development, more tin roofs, and a better transport network. Positive changes were often aligned to the price of tobacco as the major cash crop in the area; if it was low then there would be no development and the population would decrease. If the price was high, there would be an increasing population and people would be able to build modern houses. Three respondents associated the condition of the environment in 10 years' time with the state of the village, saying that it would be very hard to live here because of the damage to the environment,

including clearing and burning trees, and damage to water sources.

3.5. Current management strategies

The conflict between needing to use woodland areas now and saving them for the future was evident in several focus groups. For example, when Village D Agriculture focus group was asked about the future of the area, they said, "We need to have the reserved area, so future generations will have forest". When asked about the current availability of agricultural land, they said, "We need more land for agriculture. We need to use the land that is in the reserved area for agriculture now". This need for natural resource management has been addressed through PFM reserves and Village Land Use Management Plans (VLUMPs), with limited success. PFM reserves were established in Village C and Village E in 2011 and 2002 respectively. According to District Officer 3, these were funded by an international government development agency. PFM groups in both villages described the process as top-down: "It was a government programme, they sent people from the District Council here and said that we needed to protect resources within the village ... They decided where the reserve would be" (Village E PFM focus group). While fetching water, fruit, and firewood is allowed in the reserve, permits are needed for the collection of construction poles, timber, grasses, and bushmeat. In the 2 years since the establishment of the PFM reserve in Village C, no permits had been issued (Village C PFM focus group).

Within Village E's PFM, pastoralists had settled 2 years previously and were clearing the forest, and "although the district council knows about it, nothing is done" (Village E PFM focus group). District Officer 3 explained that funding had been available to establish the PFMs, but there is no funding now to maintain them.

VLUMPs were introduced as a result of the Tanzania National Land Use Policy (2007). There are VLUMPs in all villages apart from Village E. Although the design and implementation of these plans is supposed to be bottom-up, "the villagers are the ones that produce the plan" (Regional Officer 1). The Land Use Planning Committee in Village C explained that "someone from the district walked around the area with the village chairman and some council members and decided where there should be areas for livestock, agriculture, and a reserve. They told us what was where at the village meeting". Little consultation meant that areas for cattle were inappropriate, with no water sources or adjacent water sources to cultivation (Village B Elders focus group), and there is no funding to take the plan beyond paper: "The plans are not effective on the ground, because people just carry on as usual. The government are supposed to demarcate the different areas, but there is no funding so it is not done, so people do not know where the boundaries are" (District Officer 8).

4. Discussion

An interdisciplinary, mixed method approach provided a comprehensive assessment of provisioning ES within the miombo woodlands of the Kipembawe Division, south-west Tanzania as a typical remote miombo woodland region. Three critical provisioning ES were identified that nearly all households were dependent upon: fuelwood, building materials, and fresh water. Similar dependencies are seen throughout rural communities in sub-Saharan Africa (Egoh *et al.*, 2012).

There were no significant relationships between the number of ES used and different socio-economic factors. Kipembawe is very remote and for the majority of people, regardless of wealth, the only goods and services that are available are those that they and their neighbours produce themselves and those that can be harvested from the woodland. The findings presented here show that this situation appears to be true of all households due to the lack of alternative sources, regardless of a household's purchasing power. This finding is in contrast to that of Dewees *et al.* (2010), who found that people with low incomes were most reliant on forest goods to prevent them from falling deeper into poverty in the miombo woodland systems. Given that this relationship between poverty and provisioning ES is widely accepted (e.g., Fisher *et al.*, 2014; Suich *et al.*, 2015), our findings are significant and show that care should be taken in remote areas and that households with higher incomes, but restricted access to alternative

products, are not excluded from community-based natural resource management decision-making processes (see also Dyer *et al.*, 2014; Mathur *et al.*, 2014). Additionally, households did not gather woodland products in order to generate income, as has been found in other areas of miombo (Kalaba *et al.*, 2013). This may be due to a lack of demand, but may also be due to the relatively high income generated by tobacco cultivation, which reduces the need to seek income from elsewhere. Shackleton and Shackleton (2006) also found little difference between the use of non-timber forest products and wealth. However, they did find that wealthier households purchased more goods than poorer households; this was not the case within Kipembawe, where markets remain only weakly established.

The main ES that households perceived to be decreasing were firewood and water, both of which contribute to maintaining food security (Poppy *et al.*, 2014). Declines of these services were also seen in the tobacco cultivation landscapes in Uganda, where wetlands, savannah woodlands, and forests have been converted to agriculture (Speziale and Geneletti, 2014). Households reported that they have to travel further to fetch firewood, which reduces time spent cultivating or in education, and can reduce livelihood security (York, 1990; Ndiritu and Nyangena, 2011). Respondents within Kipembawe recognised the value that ES provide to their households and demonstrated a high level of awareness of the impact that deforestation is having on the environment. However, when asked about the future of their villages, only three of the 196 household heads connected loss of forest to loss of ES and then to the future of their villages.

Despite no detectable trend in the rainfall data recorded in this area, evidence suggests that water levels in the Lupa River have decreased since the 1970s, and villagers reported water shortages. While determining the reasons for a decrease in river water levels were beyond the scope of this research, this would be useful information to enable managed water use. Otherwise, limited water availability may lead to further reduced food security (Besada and Werner, 2015). Although 61 responses about the future of the environment were associated with a lack of water, only two responses directly cited water shortages as being a potential problem. This is important because it demonstrates that the majority of households did not recognise the impact land use change occurring today will have on the future, and can mean that actions to support sustainable use or to introduce alternative methods are not taken. This knowledge can help policymakers ensure that policy and project development focuses on enhancing people's awareness about conservation (Amin *et al.*, 2015) and sustainable use, alongside the management of ES that have been identified as important to local communities. The need for land use management within Kipembawe is recognised, as illustrated here through householders' recognition that the loss of ES will have an impact on their households, as well as government attempts to establish land use management plans and protected areas. Given the multiple demands on

this landscape (ecosystem service provision, biodiversity conservation, agriculture, and livestock keeping; Jew, 2016), an adaptive management strategy that can maintain multiple objectives over time (Milder *et al.*, 2014) and encourage multi-stakeholder dialogue and social learning is appropriate (Guariguata *et al.*, 2012). While initially a top-down approach may be necessary to kick-start the process (or re-invigorate those already in place), participation, engagement, and empowerment of local communities to expand their awareness and their role in management is vital. Such an approach can be described as adaptive co-management, where collaboration is encouraged between communities, policymakers, and multiple levels of governance (Armitage *et al.*, 2008), and a shared process of learning leads to adaptive, cohesive decision making to successfully deliver positive ecological and social outcomes (Plummer *et al.*, 2017).

Agricultural expansion offers short term economic benefits, yet these are unlikely to justify long term impacts on ES (Carreño *et al.*, 2012), particularly in remote locations where alternative options are limited. It is difficult to determine whether reductions in the provisioning services discussed above are a result of land use change, increasing populations which lead to more demand, or a combination of the two; however they are inextricably linked and reductions in the availability of critical provisioning ES per household will have negative impacts on the household and local livelihoods.

5. Conclusion

Land use change within miombo woodlands that results in the diminishing availability of critical provisioning ES will have a substantial negative impact on the livelihoods of local communities who are dependent upon them. Our findings show that this will be particularly significant in remote areas, where access to alternative goods and services is limited and all households are vulnerable to change, regardless of their economic status. Sustainable use of provisioning ES is necessary to guarantee their availability into the future. Community-based natural resource management could develop strategies that include zones for agricultural use, restricted access, open access, and protected areas. These would need to be developed according to site specific factors such as ecosystem service use, projected population changes, biodiversity, and agricultural needs. Sustaining and empowering natural resource management through periods of agricultural expansion will be vital for sustainable management of miombo woodland systems.

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